Introducing first and second generation biofuels into GTAP 9 Data Base

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1. Introduction

The standard GTAP data bases do not explicitly represent production, consumption, and trade of biofuels. In response to the growing demand for biofuels research, biofuels (including ethanol produced from grains, ethanol produced from sugarcane, and biodiesel produced from vegetable oils) were introduced in to the GTAP data base version 6 which represents the global economy in 2001 [1]. In 2001 the global production of biofuels (including ethanol and biodiesel) was about 5 billion gallons. Then the first and second generation of biofuels were introduced into the GTAP data base version 7 for 2004 [2]. In 2004 the global production of all types of first generation of biofuels was about 7.8 billion gallons. In 2004, there was no commercial production of second generation of biofuels (biofuels produced from cellulosic materials). However, several second generation biofuel technologies were introduced into this data base. Several studies have used the first and second versions of the GTAP-BIO data bases to project the economic and land use impacts of biofuel production and policy at the global scale [3-8].

More recently a new version of the GTAP data base has been released which represents the global economy in 2011. This data base, like the earlier versions, does not include biofuel production and consumption. During the period of 2004-2011, significant changes have occurred in different regions in the world, mainly in energy and agricultural markets. Biofuel production has increased rapidly from 7.8 billion gallons in 2004 to 23 billion gallons in 2011 at the global scale, a tremendous growth of 19.5% in the eight year period. Agricultural crops such as maize, soybeans, rapeseed, and sugarcane constitute the main biofuel feedstocks. Thus, these crops have faced an increase in demand to support production of biofuels. In addition demands for crops have increased to produce more food and feed in response to population and income growth across the world. As a consequence, there have been changes in crop mix produced across the world and in agricultural crop prices. Global harvested area has changed and land use has altered in different regions as well. Hence, the standard GTAP data base has to be modified to add production,

consumption, and trade of biofuels along with a wide range of other modifications to be used as part of the data base for the GTAP-BIO model and analyses. In addition, the GTAP land use data base must be updated to 2011 as a compliment for the GTAP-BIO data base. To provide these data bases we collected many data items and followed many steps and procedures as explained in the rest of this report. In what follows we explain all of the actions which we implemented to introduce biofuels into the new GTAP data base. Pena-Levano described development of the new land data base for 2011 [9].

2. Introducing biofuels into the standard GTAP database.

In developing the earlier versions of the GTAP-BIO data base we made many modifications in the data base to properly model biofuel production and policy. Those modifications were repeated for the new data base. To accomplish this task, we collected all the required data and developed the needed programs and codes to introduce the biofuels and by products into the data base.

2.1. Data collection

The following main data items are collected for various sources:

- Production and consumption of biofuels for 2011 are taken from the US Energy Information Administration (EIA) web site (www.eia.gov). The EIA provides data on ethanol and biodiesel produced across the world by country. Table 1 represents an aggregated version of this data by 19 regions represented in GTAP-BIO.

- Harvested area, crop produced, area of forest, pasture and cropland for 2011 is obtained from the FAOSTAT data base http://faostat3.fao.org/home\E, for details see Pena-Levano [9].

- Data on vegetable oils and meals produced, consumed and traded is collected by country from the World oil data base and used to split the GTAP vegetable oil industry (sector) into different types of vegetable oils and meals, as described later on in this report.

Table 1. Biofuel production in 2011 (million gallons)

Region	Ethanol	Biodiesel
USA	13,929.1	967.5
European Union	1,108.4	2,731.0
BRAZIL	6,009.4	706.1
Canada	459.9	41.4
JAPAN	15.3	4.6
China	605.5	136.4
India	92.0	30.7
Central America	162.5	2.0
South America	208.5	876.3
East Asia	0.0	96.6
Malaysia and Indonesia	1.5	321.9
South East Asia	159.4	202.4
South Asia	3.1	0.0
Russia	0.0	0.0
Central Europe	14.1	41.2
Other European countries	0.0	1.5
Middle East and North Africa	0.0	1.5
Sub Saharan Africa	9.5	2.6
Oceania	116.5	25.6
Total	22,894.8	6,189.3

Source: US Energy Information Administration (www.eia.gov)

2.2. Dividing standard GTAP crop activities in to new groups

The following standard GTAP sectors are divided into new sectors:

- Coarse grains (gro) is divided into: Sorghum and other coarse grains,
- Oilseeds (osd) is divided to: Soybeans, rapeseed, palm, and other oilseeds,
- Vegetable oil (vol) is divided into: vegetable oil soy, vegetable oil palm, vegetable oil rapeseed, vegetable oil other, and their corresponding meals,
- Food (ofd) is divided into: Food and feed,
- A tiny miscanthus sector is introduced into the data base,
- A tiny switchgrass sector is introduced into the data base,

- A dummy sector is introduced for cropland pasture (this version includes cropland pasture in Canada as well as the US and Brazil),
- A new industry which collects corn stover for biofuel production is introduced.

For each of these cases we use the SplitCom program and a supporting procedure (developed as a TABLO code) to split the targeted sector. Tables 2.1, 2.2, and 2.3 represent the values of these new commodities in the new data base. The tiny cellulosic sectors do not appear in this table.

Table 2.1. Market values of some new non-biofuel items in 2011 (Million $)

Region	Sorghum	Other Coarse Grains	Soybeans	Palm fruit	Rapeseed	Other Oilseeds
USA	1498	84234	36635	0	1449	3454
European Union	81	35793	382	0	14025	9449
BRAZIL	345	15713	28013	133	336	3119
Canada	0	4386	1935	0	6249	1536
JAPAN	0	148	324	0	4	18
China	347	61103	11288	69	10504	10367
India	1416	11735	9981	0	6428	12531
Central America	796	9272	231	373	1	870
South America	830	14373	20235	407	332	4701
East Asia	5	392	560	0	14	135
Malaysia and Indonesia	0	4984	1318	21710	0	7931
South East Asia	72	4356	190	208	0	2446
South Asia	40	1651	195	0	1366	4018
Russia	8	4320	382	0	268	2321
Central Europe	19	12564	668	0	856	4501
Other European countries	0	1406	5	0	253	98
Middle E. and N. Africa	517	17974	102	0	228	5406
Sub Saharan Africa	6356	43012	1346	3892	81	18425
Oceania	117	2680	12	82	1478	479
Total	12446	330098	113800	26873	43872	91804

Table 2.2. Market values of some new non-biofuel items in 2011 (Million $)

Region	Processed food	Processed feed	Pasture land	Vegetable oil-Soy	Meal-Soy	Vegetable oil-Palm
USA	330905	33968	601	14340	11537	3
European Union	600309	24467	0	1591	743	15
BRAZIL	76551	11690	410	18695	10762	892
Canada	43588	3873	227	640	523	2
JAPAN	193039	10179	0	1809	1332	2
China	435310	76451	0	32073	20746	103
India	73032	2036	0	5563	2274	819
Central America	95863	4757	0	2243	902	1512
South America	91076	8122	0	14626	6536	2025
East Asia	45378	8893	0	1669	1223	0
Malaysia and Indonesia	66580	4320	0	1177	939	50382
South East Asia	64266	7386	0	898	382	1717
South Asia	35002	1006	0	156	52	4
Russia	53964	5122	0	776	370	2
Central Europe	74882	3496	0	925	401	4
Other European countries	36074	1895	0	276	122	0
Middle E. and N. Africa	89836	5078	0	1511	615	1
Sub Saharan Africa	64120	3661	0	243	92	2196
Oceania	43530	1272	0	9	5	773
Total	2513305	217671	1239	99219	59558	60454

Table 2.3. Market value of some new non-biofuel items in 2011 (Million $)

Region	Meal-Palm	Vegetable oil-Rapeseed	Meal-Rapeseed	Vegetable oil-Others	Meal-Others
USA	1	713	252	7046	2477
European Union	2	15982	2998	27036	6366
BRAZIL	74	71	17	3282	455
Canada	0	4321	1315	1278	312
JAPAN	0	1934	587	1239	370
China	12	15965	4271	24716	6292
India	85	4745	1251	10642	2701
Central America	80	801	168	1606	346
South America	141	62	13	5324	1146
East Asia	0	52	18	792	196
Malaysia and Indonesia	4249	1	0	7207	1592
South East Asia	75	26	6	3528	686
South Asia	0	1793	413	4216	969
Russia	0	446	93	5151	1085
Central Europe	0	643	131	9870	2010
Other European countries	0	150	33	711	158
Middle E. and N. Africa	0	804	168	2537	542
Sub Saharan Africa	98	33	7	3004	614
Oceania	45	336	66	1090	205
World	4863	48878	11808	120276	28521

2.3. First generation bio-fuels introduced into the new data base

The first generation of biofuels are divided into grain ethanol (either from corn or wheat), sorghum ethanol, sugarcane ethanol, soy biodiesel, palm biodiesel, rapeseed biodiesel, and other biodiesel, and these are added to the data base. To accomplish this task the share of each feedstock in ethanol or biodiesel produced in each region is determined from various supporting resources. Following our earlier work [1 and 2], using proper cost structures, biofuels are introduced into the new data base. In each case we used the SplitCom program and a TABLO code to accomplish the split process. We also developed a program to introduce DDGS (produced in conjunction with grain ethanol) into the data base. All of these items are evaluated at market prices in 2011. Table 3 represents values of biofuels produced in 2011.

Table 3. Values of first generation biofuels in 2011 (Million $)

Region	Corn or wheat ethanol	Sugarcane ethanol	Sorghum ethanol	Soy biodiesel	Palm biodiesel	Rape biodiesel	Other biodiesel
USA	35646	1	1	2527	545	495	1387
European Union	1379	963	0	1197	736	7259	4557
BRAZIL	0	15382	0	2089	181	0	1345
Canada	950	0	0	0	0	14	198
JAPAN	0	40	0	0	0	2	22
China	1265	1	0	0	0	0	620
India	0	236	0	0	0	0	157
Central America	0	416	0	0	0	0	0
South America	0	534	0	4487	0	0	0
East Asia	0	20	0	57	57	0	458
Malaysia and Indonesia	0	4	0	0	1648	0	0
South East Asia	0	408	0	104	104	0	829
South Asia	0	8	0	0	0	0	0
Russia	0	0	0	0	0	0	0
Central Europe	20	12	0	21	0	21	169
Other European countries	0	0	0	0	2	0	6
Middle E. and N. Africa	0	0	0	0	0	0	8
Sub Saharan Africa	13	8	0	0	4	0	9
Oceania	211	41	0	0	0	13	118
World	39485	18075	2	10483	3277	7805	9885

2.4. Second generation bio-fuels introduced into the new data base

We introduced the following advanced biofuels into the data base with tiny quantities:

- A bio-gasoline sector and an ethanol sector from corn stover,
- A bio-gasoline sector and an ethanol sector from miscanthus,
- A bio-gasoline sector and an ethanol sector from switchgrass.

To accomplish this task we followed Taheripour and Tyner [2]. The cost structure of each biofuel provided by these authors is updated to 2011 market values. Table 4 contains the second generation biofuel values.

Table 4. Values of second generation biofuels in 2011 (Million $)

Region	Miscanthus advanced biogasoline	Switchgrass advanced biogasoline	Stover advanced biogasoline	Miscanthus advanced Ethanol	Switchgrass advanced ethanol	Stover advanced ethanol
USA	2.5	2.3	2.2	3.1	3.0	2.6
European Union	2.5	2.4	2.2	3.1	3.0	2.6
BRAZIL	2.4	2.3	2.1	3.1	2.9	2.5
Canada	0.0	0.0	0.0	0.0	0.0	0.0
JAPAN	0.0	0.0	0.0	0.0	0.0	0.0
China	0.1	0.1	0.1	0.1	0.1	0.1
India	0.0	0.0	0.0	0.0	0.0	0.0
Central America	0.0	0.0	0.0	0.0	0.0	0.0
South America	0.0	0.0	0.0	0.0	0.0	0.0
East Asia	0.0	0.0	0.0	0.0	0.0	0.0
Malaysia and Indonesia	0.0	0.0	0.0	0.0	0.0	0.0
South East Asia	0.0	0.0	0.0	0.0	0.0	0.0
South Asia	0.0	0.0	0.0	0.0	0.0	0.0
Russia	0.0	0.0	0.0	0.0	0.0	0.0
Central Europe	0.0	0.0	0.0	0.0	0.0	0.0
Other European countries	0.0	0.0	0.0	0.0	0.0	0.0
Middle E. and N. Africa	0.0	0.0	0.0	0.0	0.0	0.0
Sub Saharan Africa	0.0	0.0	0.0	0.0	0.0	0.0
Oceania	0.0	0.0	0.0	0.0	0.0	0.0
World	7.7	7.3	6.7	9.7	9.3	8.1

2.5. Other basic modifications

The following major modifications were made in the GTAP standard data base as well:

- Feed demands in the base data was restructured to match actual market data from USDA on feed demand,
- GTAP standard carbon emissions data was modified to match the structure of the GTAP-BIO data base,
- The standard GTAP data base misrepresents vegetable oil production in USA and China. We fixed the issue using the World Oil data base,
- Some changes are made to avoid negative numbers when we introduced biofuels into the data base,

- Distribution of coarse grains production across users in US was modified to match real world data from USDA,
- Cropland pasture was added for Canada, and proper changes are made in the input output table of this country, Cropland pasture was updated for the US and Brazil.
- Land rent is divided across AEZs following [10],
- Land use headers for 2011 were added to the data base.

The GTAPADJUST program and several TABLO codes were used to implement the above modifications.

Following the above modifications, we have now a GTAP-BIO data base for 2011 based on the final version of the standard GTAP data base for 2011.

3. Overview of the GTAP-BIO data bases versions 7 and 9

In this section we compare the GTAP-BIO data bases versions 7 and 9 which represent the world economy in 2004 and 2011, respectively. We begin with macro variables and then move to the sectoral level. It is important to note that the GTAP data bases represent nominal values measured in current US$ for each data year. This means that the 2004 and 2011 data bases represent current monetary values measures in 2004 US$ and 2011 US$ prices. Hence, when we compare monetary values of these data bases, our comparisons do not reflect changes in real values.

2.1. Macro variables

Population

At the global scale population increased from 6,404 million in 2004 to 6,955 million in 2011, a net increase of 550 million people or 8% (Table 5). Three regions including Sub-Saharan Africa (with 144 million), India (with 134 million), and Middle East & North Africa (with 48.3 million) had the largest shares in the population growth over this time period.

Table 5. Population by region in 2004 and 2011

Region	Population in 2004 (million)	Population in 2011 (million)	Absolute Change (million)	Share in change (%)	Cumulative growth (%)
USA	295.4	311.6	16.2	2.9	5.5
European Union	487.8	503.5	15.7	2.8	3.2
BRAZIL	183.9	196.9	13.0	2.4	7.1
Canada	32.0	34.3	2.4	0.4	7.5
JAPAN	127.9	127.8	-0.1	0.0	-0.1
China	1,314.9	1,351.2	36.3	6.6	2.8
India	1,087.1	1,221.2	134.0	24.4	12.3
Central America	183.4	203.7	20.3	3.7	11.1
South America	186.1	201.3	15.2	2.8	8.1
East Asia	95.8	100.9	5.1	0.9	5.4
Malaysia and Indonesia	245.0	272.6	27.6	5.0	11.3
South East Asia	303.6	329.7	26.1	4.7	8.6
South Asia	370.9	407.2	36.3	6.6	9.8
Russia	143.9	143.0	-0.9	-0.2	-0.7
Central Europe	228.5	234.1	5.6	1.0	2.5
Other European countries	12.2	13.2	1.1	0.2	8.7
Middle E. and N. Africa	339.0	387.3	48.3	8.8	14.2
Sub Saharan Africa	734.6	878.8	144.2	26.2	19.6
Oceania	32.6	36.8	4.2	0.8	12.8
World	6404.7	6955.1	550.4	100.0	8.6

GDP and GDP per capita at current prices

The value of global GDP was about $40,960 billion in 2004. The shares of European Union (EU), US, and Japan in the global output were about 31.5%, 28.5% and 11.4% in 2004. China was the fourth largest economy in 2004 with 4.5% share of global output (Table 6).

Table 6. GDP at current prices by region in 2004 and 2011

Region	GDP in 2004 (billion $)	Share in 2011 (%)	GDP in 2011 (billion $)	Share in 2011 (%)	Cumulative growth (%)
USA	11,673.6	28.5	15,542.8	21.7	33.1
European Union	12,883.2	31.5	17,611.4	24.6	36.7
BRAZIL	618.0	1.5	2,478.1	3.5	301.0
Canada	979.2	2.4	1,779.4	2.5	81.7
JAPAN	4,658.8	11.4	5,905.8	8.3	26.8
China	1,838.7	4.5	7,566.0	10.6	311.5
India	634.1	1.5	1,880.2	2.6	196.5
Central America	970.3	2.4	1,655.8	2.3	70.6
South America	579.6	1.4	1,818.0	2.5	213.7
East Asia	1,007.5	2.5	1,727.8	2.4	71.5
Malaysia and Indonesia	373.6	0.9	1,135.8	1.6	204.0
South East Asia	416.6	1.0	1,074.1	1.5	157.8
South Asia	184.6	0.5	425.5	0.6	130.5
Russia	569.9	1.4	1,905.0	2.7	234.3
Central Europe	552.8	1.3	1,549.4	2.2	180.3
Other European countries	623.3	1.5	1,169.9	1.6	87.7
Middle E. and N. Africa	1,116.7	2.7	3,213.7	4.5	187.8
Sub Saharan Africa	524.0	1.3	1,460.9	2.0	178.8
Oceania	755.5	1.8	1,595.4	2.2	111.2
World	40,960.1	100.0	71,494.8	100.0	74.5

The value of global output has increased to $71,491 billion in 2011. The EU and US were the two largest blocks in 2011 as well. However, their shares of global output dropped to 24.6% and 21.7%, respectively. Japan lost the third rank to China in 2011. China had the largest nominal growth (312%) between 2004 and 2011, and its share in the global output increased to 10.6% in 2011. Brazil also experienced rapid growth between 2004 and 2011. Its nominal GDP increased from $618 billion in 2004 to $2,476 billion in 2011 (Table 6). In real terms GDP of China increased 3.2 times faster than GDP of Brazil in this time period, 107.8% cumulative growth in China versus 33.2% in Brazil[1].

[1] Real growth rates were obtained from the World Bank data base.

The price of crude oil (and other energy products) increased during the time period of 2004-2011[2], and that increased the share of major oil producing countries in global output. The global GDP share of Middle E. and N. Africa increased from 2.7% in 2004 to 4.5% in 2011 (Table 6).

The ranking of countries based on per capita GDP remained relatively stable as shown in Table 7. This table indicates that the five poorest regions in 2011 were Rest of South Asia (rank 19 with $1,045 GDP per capita), India (rank 18), Sub-Saharan Africa (rank 17), Rest of South East Asia (rank 16), and China (rank 15). The top five richest region in 2011 were Other European countries (rank 1 with $88,472 GDP per capita), Canada (rank 2), USA (rank 3), Japan (rank4) and Oceania (rank 5). The per capita GDP of the richest region was 85 times of the GDP per capita of the poorest region in 2011.

Table 7. GDP per capita by region in 4004 and 2011

Region	GDP per capita in 2004 ($)	Rank in 2011	GDP per capita in 2011 ($)	Rank in 2011	Cumulative growth (%)
USA	39,517	2	49,883	3	26
European Union	26,411	5	34,979	6	32
BRAZIL	3,360	10	12,583	9	274
Canada	30,639	4	51,812	2	69
JAPAN	36,419	3	46,205	4	27
China	1,398	15	5,599	14	300
India	583	18	1,540	18	164
Central America	5,289	8	8,128	12	54
South America	3,114	12	9,031	10	190
East Asia	10,521	7	17,123	7	63
Malaysia and Indonesia	1,525	14	4,167	15	173
South East Asia	1,372	16	3,258	16	137
South Asia	498	19	1,045	19	110
Russia	3,960	9	13,326	8	237
Central Europe	2,419	13	6,618	13	174
Other European countries	51,241	1	88,476	1	73
Middle E. and N. Africa	3,294	11	8,299	11	152
Sub Saharan Africa	713	17	1,662	17	133
Oceania	23,143	6	43,318	5	87
World	6,395	-	10,279	-	61

[2] For example, the Brent spot price of crude oil increased from $38.26 per barrel in 2004 to $111.26 per barrel in 2011 (both nominal values).

Expenditures

Table 8 shows the distribution of GDP between major expenditure items including Consumption (C), Investment (I), Government (G), Exports (X) and Imports (M) by region in 2004 and 2011.

Table 8. Shares of consumption, investment, government, exports, and imports by region in GDP in 2004 and 2011

Region	2004 (%)					2011 (%)					Difference (2011-2004)				
	C	I	G	X	M	C	I	G	X	M	C	I	G	X	M
USA	70.5	18.8	15.5	9.3	-14.2	70.1	18.5	16.5	12.1	-17.2	-0.4	-0.3	1.0	2.8	-3.0
European Union	59.6	19.9	21.0	32.5	-32.9	59.9	19.0	22.0	39.3	-40.3	0.3	-0.9	1.0	6.9	-7.3
BRAZIL	55.7	19.7	18.9	18.8	-13.2	60.1	19.2	20.6	11.2	-11.0	4.3	-0.6	1.7	-7.6	2.3
Canada	57.3	21.0	20.2	33.5	-32.0	55.1	23.2	21.5	27.1	-26.8	-2.2	2.2	1.2	-6.4	5.2
JAPAN	56.4	23.5	17.6	14.1	-11.6	59.7	20.4	20.2	16.0	-16.2	3.2	-3.1	2.6	1.9	-4.6
China	43.1	39.3	11.2	45.0	-38.6	37.1	45.4	13.4	28.3	-24.2	-5.9	6.1	2.1	-16.7	14.4
India	67.3	24.7	11.7	16.4	-20.1	62.3	33.8	12.1	19.9	-28.1	-5.0	9.1	0.5	3.5	-8.0
Central America	69.8	21.5	10.7	27.9	-29.9	67.9	20.0	12.9	31.1	-31.9	-1.9	-1.5	2.2	3.2	-2.0
South America	60.5	19.3	12.8	29.3	-21.8	62.5	21.1	13.4	23.4	-20.4	2.0	1.8	0.6	-5.9	1.5
East Asia	51.9	25.4	12.5	54.1	-44.0	52.8	27.7	13.5	58.8	-52.8	0.9	2.3	1.0	4.7	-8.8
Malaysia and Indonesia	57.3	17.8	8.5	65.1	-48.8	56.0	30.3	10.4	39.8	-36.6	-1.3	12.5	1.9	-25.3	12.2
South East Asia	57.9	25.2	10.4	92.3	-85.9	60.2	26.1	11.3	72.3	-69.9	2.3	0.8	0.9	-20.0	16.0
South Asia	80.3	21.1	8.4	20.5	-30.3	83.4	19.5	10.2	18.1	-31.1	3.1	-1.6	1.8	-2.4	-0.9
Russia	50.9	18.7	17.0	36.0	-22.5	49.5	21.8	18.5	29.3	-19.0	-1.4	3.1	1.4	-6.7	3.5
Central Europe	68.9	22.9	15.9	38.2	-45.9	66.5	23.1	15.3	32.2	-37.0	-2.4	0.2	-0.6	-6.1	8.8
Other European countries	53.9	19.8	16.3	44.4	-34.4	52.6	20.9	16.3	47.3	-37.1	-1.3	1.1	0.0	2.8	-2.6
Middle E. and N. Africa	50.4	22.0	20.1	45.8	-38.2	46.8	24.5	16.5	45.2	-33.0	-3.6	2.5	-3.6	-0.5	5.1
Sub Saharan Africa	61.9	18.9	17.5	36.1	-34.5	64.5	20.1	15.1	31.3	-31.0	2.6	1.2	-2.5	-4.8	3.4
Oceania	59.9	24.3	18.0	19.2	-21.4	54.8	26.0	18.3	21.8	-20.9	-5.1	1.7	0.3	2.6	0.5
World	61.4	21.3	17.3	25.6	-25.6	58.9	23.5	17.6	28.2	-28.2	-2.5	2.2	0.3	2.6	-2.6

In general Table 8 shows that:

- The share of consumption expenditures in global output was about 59% in 2011, slightly lower than 61% of 2004.
- The share of investment in global output was about 24% in 2011, slightly higher than 21% of 2004.

- The share of government expenditure in global output was about 17% in both 2004 and 2011.
- The share of exports (as an index for global trade) in global output was about 28% in 2011, slightly higher than 26% of 2004.
- Among the five richest regions mentioned above, the US has the highest consumption share (about 70%) and the lowest investment share (about 19%) of GDP in both years.
- Among the five poorest regions mentioned above, China has the lowest consumption share (43% in 2004 and 37% in 2011) and the highest investment share (39% in 2004 and 45% in 2011) in GDP.
- The poorest region, Rest of South Asia, consumes a very large portion of its GDP in both years and suffers from a major trade deficit. This region consumed (sum of C and G) about 94% of its GDP in 2011, similar to 2004.
- The regional distribution of GDP between consumption, investment, and government expenditures in 2004 and 2011 are not very different. The only exceptions are related to the shares of consumption and investment in China and India. The share of consumption dropped in favor of expansion in the share of investment in these two countries between 2004 and 2011. The share of investment in Malaysia-Indonesia also increased significantly in this time period.
- Finally, the share of exports in GDP has changed significantly in several regions between 2004 and 2011. For example, the Chinese export share dropped significantly (from 45% to 28%), Malaysia-Indonesia (from 65% to 40%), and Rest of South East Asia (from 92% to 72%).

Saving and Investment

At the global scale nominal saving (and therefore investment) increased from $4,288 billion in 2004 to $7,354 billion in 2011 (Table 9).

Table 9. Saving and investment by region in 2004 and 2011

Region	Saving (billion $)			Investment (billion $)			Net Saving (billion $)		
	2004	2011	%Change	2004	2011	%Change	2004	2011	%Change
USA	585	157	-73.1	1,153	951	-17.5	-568	-793	39.7
European Union	998	823	-17.6	1,059	986	-6.8	-61	-164	168.4
BRAZIL	86	118	37.5	51	112	120.2	35	6	-83.8
Canada	122	207	70.4	107	202	88.8	15	5	-65.0
JAPAN	539	163	-69.7	423	177	-58.1	116	-14	-111.6
China	664	2,674	302.9	546	2,362	332.8	118	313	164.6
India	79	307	291.3	102	462	353.7	-23	-155	564.7
Central America	76	151	98.9	96	164	71.7	-20	-13	-32.3
South America	101	193	92.1	58	138	140.5	43	55	27.2
East Asia	251	354	40.7	149	250	67.3	102	104	1.7
Malaysia and Indonesia	93	228	144.4	32	191	496.2	61	37	-39.7
South East Asia	60	140	131.2	34	114	236.6	27	26	-3.1
South Asia	5	-21	-548.1	23	35	53.3	-18	-56	208.9
Russia	157	341	117.8	80	146	83.2	77	195	153.8
Central Europe	24	120	398.5	66	195	194.2	-42	-75	78.2
Other European countries	107	235	119.5	45	116	158.6	62	120	91.4
Middle E. and N. Africa	211	789	274.4	126	397	214.3	84	392	364.4
Sub Saharan Africa	44	175	299.6	35	171	386.4	9	4	-56.2
Oceania	88	200	127.1	105	185	76.9	-17	15	-187.4
World	4,288	7,353	71.5	4,288	7,353	71.5	0	0	-

The growth rate in saving (measured in cumulative percent change) varies across regions. Saving has decreased in three rich regions including US, EU, and Japan by 73.7%, 17.2% and 69.7% between 2004 and 2011. Rest of South Asia (the poorest region) also experienced a reduction in saving, from positive $5 billion to negative $21 billion. In all other regions saving has increased significantly. Investment follows more or less the same pattern as shown in Table 9.

Net savings (Saving – Investment) has decreased in the US from -$568 billion to -$796 billion due to a reduction in saving in this country[3]. The EU and Japan also had a reduction in net saving (from -$61 billion to -$161 billion in EU and from $116 billion to -$14 billion in Japan). Net savings has increased in China (from $118 billion to $311 billion), Russia (from $77 billion to $194 billion), and Middle East & North Africa (from $84 billion to $392 billion) basically due to reduction in investment. Net savings has dropped (from -$23 billion to -$155 billion) in India due to expansion in investment in this country as shown in Table 9. Again, readers are reminded that these changes are in nominal terms.

Factor income distribution

Table 10 represents the distribution of income across primary inputs including land, labor, capital, and natural resources in 2004 and 2011. This table indicates that the shares of these inputs in income at the global scale were about 1.5%, 50.4, 46.3%, and 1.8% in 2011. These figures are not very different from their corresponding shares in 2004. As these figures indicate, land and natural resources receive a small portion of global income. In general, this picture holds at the regional level, of course with some exceptions. For example, the share of land in income in some developing regions is significantly higher than the global average. In India the share of land reaches 8% of total income. The same conclusion can be made for the share of natural resources in total income. The natural resources share is small with some exceptions. For example, in Middle East & North Africa natural resources represents about 10% of income. In Russia, the share of natural resources in income is also relatively high (about 7%).

In general distribution of income across primary factors is not very different between 2004 and 2011 as shown in Table 10. However, one can see that in many regions capital receives a slightly higher share in 2011 with some exceptions. For example, in China, India, and Sub-Saharan Africa the share of capital decreased significantly in favor of labor in 2011 compared with 2004. It is also important to note that between 2004 and 2011 the share of land in income has increased only in a few regions including US, Japan, Rest of South East Asia, Other European Countries, and Sub- Saharan Africa (Table 10).

[3] In US, the real net saving at constant 2011 prices also decreased from -$659 in 2004 to -$793 in 2011. The deflator used for this calculation is the GDP deflator from the US Department of Commerce.

Table 10. Distribution of income across primary factors by region in 2004 and 2011

Region	2004				2011				Difference 2011-2004			
	Land (%)	Labor (%)	Capital (%)	Nat. Res.(%)	Land (%)	Labor (%)	Capital (%)	Nat. Res.(%)	Land	Labor	Capital	Nat. Res.
USA	0.43	66.58	32.59	0.39	0.55	65.64	33.14	0.68	0.11	-0.95	0.55	0.29
European Union	0.96	44.97	53.77	0.30	0.53	43.83	55.27	0.37	-0.43	-1.14	1.50	0.08
BRAZIL	1.28	52.52	45.23	0.97	1.10	54.92	43.10	0.88	-0.17	2.39	-2.13	-0.09
Canada	0.83	53.13	44.03	2.00	0.63	53.20	43.68	2.50	-0.21	0.06	-0.35	0.50
JAPAN	0.32	55.33	44.25	0.11	0.34	51.48	48.08	0.10	0.03	-3.84	3.83	-0.01
China	3.87	49.26	44.74	2.14	3.14	54.75	40.52	1.59	-0.73	5.50	-4.22	-0.54
India	8.44	45.72	44.70	1.14	8.00	50.58	40.54	0.89	-0.44	4.85	-4.16	-0.25
Central America	2.30	43.89	52.83	0.98	1.38	38.24	59.60	0.79	-0.92	-5.66	6.77	-0.19
South America	2.53	49.32	44.74	3.41	2.09	49.12	45.83	2.95	-0.44	-0.19	1.09	-0.46
East Asia	1.77	51.10	46.88	0.25	1.10	49.53	49.09	0.28	-0.67	-1.57	2.21	0.03
Malaysia and Indonesia	6.07	43.65	46.56	3.72	5.21	43.87	47.48	3.44	-0.86	0.23	0.92	-0.28
South East Asia	3.64	38.84	55.99	1.52	4.55	40.16	53.63	1.67	0.91	1.31	-2.37	0.15
South Asia	8.16	47.25	43.61	0.97	6.62	34.43	57.98	0.96	-1.54	-12.82	14.37	-0.01
Russia	2.09	34.20	56.75	6.96	1.31	30.59	60.60	7.51	-0.78	-3.61	3.84	0.55
Central Europe	2.30	44.92	51.06	1.72	1.89	41.91	53.06	3.14	-0.40	-3.01	2.00	1.42
Other European countries	0.55	47.25	49.12	3.07	0.61	51.06	44.94	3.39	0.06	3.81	-4.18	0.32
Middle E. and N. Africa	0.71	27.39	62.16	9.74	0.57	26.00	62.58	10.85	-0.14	-1.39	0.42	1.11
Sub Saharan Africa	2.85	39.83	52.47	4.86	3.05	47.30	44.35	5.30	0.20	7.47	-8.11	0.45
Oceania	0.87	54.36	43.38	1.38	0.74	53.44	43.61	2.22	-0.14	-0.93	0.22	0.84
World	1.29	52.69	44.90	1.12	1.53	50.44	46.25	1.79	0.24	-2.25	1.35	0.66

Distribution of gross output by commodity

Table 11 represents distribution of gross output (sum of values of all commodities produced – sum over VOM[4]) of each region into five broad categories of: Agriculture (Agr.), Food and Feed (F. & F.), Biofuels (Bio.), Traditional Energy (T.E.), and Other Products (Oth.). This classification is used to highlight the impacts of biofuel production on the mix of global output.

[4] VOM of each commodity represents value of output of that commodity at market price and it covers values of intermediate and primary inputs used in the production process of that commodity.

Table 11. Distribution of gross output across major products by region in 2004 and 2011

Regions	2004					2011					Difference 2004-2011				
	Agr. (%)	F.&F. (%)	Bio. (%)	T.E. (%)	Oth. (%)	Agr. (%)	F.&F. (%)	Bio. (%)	T.E. (%)	Oth. (%)	Agr.	F.&F.	Bio.	T.E.	Oth.
USA	1.26	3.23	0.03	4.00	91.48	1.48	3.26	0.14	5.46	89.66	0.22	0.03	0.11	1.46	-1.82
European Union	1.92	5.66	0.01	3.00	89.41	1.86	5.88	0.06	6.07	86.13	-0.06	0.22	0.05	3.07	-3.29
BRAZIL	6.34	7.71	0.61	8.29	77.05	6.27	8.94	0.55	5.67	78.57	-0.07	1.23	-0.06	-2.62	1.52
Canada	2.32	4.13	0.01	6.80	86.75	2.49	5.02	0.03	10.05	82.41	0.17	0.89	0.03	3.26	-4.34
JAPAN	1.15	3.97	0.00	2.70	92.18	1.18	4.52	0.00	5.43	88.87	0.03	0.54	0.00	2.73	-3.31
China	6.50	4.07	0.00	6.59	82.84	4.93	5.21	0.03	5.76	84.08	-1.57	1.14	0.02	-0.83	1.23
India	12.74	8.23	0.01	9.91	69.12	12.47	7.07	0.09	11.13	69.24	-0.26	-1.17	0.08	1.23	0.12
Central America	4.53	9.28	0.00	7.86	78.32	4.25	8.82	0.03	7.99	78.90	-0.28	-0.47	0.03	0.14	0.58
South America	7.11	9.71	0.00	11.61	71.57	7.03	10.48	0.18	11.06	71.25	-0.08	0.76	0.18	-0.55	-0.32
East Asia	1.67	3.05	0.00	5.91	89.37	1.62	3.07	0.02	7.72	87.58	-0.06	0.02	0.02	1.82	-1.79
Malaysia and Indonesia	7.26	7.99	0.00	10.42	74.33	6.60	9.13	0.12	9.74	74.41	-0.66	1.14	0.12	-0.68	0.08
South East Asia	4.36	6.82	0.00	7.97	80.85	6.01	8.36	0.09	9.68	75.87	1.65	1.54	0.08	1.71	-4.98
South Asia	16.33	9.55	0.00	6.69	67.43	11.81	16.27	0.11	6.55	65.26	-4.52	6.72	0.11	-0.15	-2.16
Russia	4.94	5.16	0.00	24.08	65.82	3.13	6.16	0.04	26.44	64.24	-1.80	1.00	0.04	2.36	-1.58
Central Europe	8.80	7.02	0.00	14.30	69.88	6.30	7.05	0.07	14.81	71.76	-2.50	0.03	0.07	0.51	1.89
Other European countries	1.08	3.78	0.00	6.51	88.63	1.09	4.73	0.01	8.38	85.79	0.01	0.95	0.01	1.87	-2.84
Middle E. and N. Africa	5.39	4.57	0.00	28.19	61.85	4.89	4.46	0.01	33.41	57.22	-0.50	-0.11	0.01	5.22	-4.63
Sub Saharan Africa	9.92	7.47	0.00	10.64	71.97	14.31	8.88	0.03	13.28	63.51	4.39	1.41	0.03	2.64	-8.46
Oceania	3.07	5.49	0.00	4.62	86.82	3.28	4.88	0.01	7.15	84.68	0.21	-0.61	0.01	2.53	-2.15
World	2.79	4.84	0.02	5.43	86.93	3.66	5.74	0.06	8.75	81.79	0.87	0.91	0.04	3.32	-5.14

Table 11 shows that in general agriculture has a small share in gross output across the world and in particular in rich regions such as US, EU, Japan, and Other European Countries. The share of agriculture in gross output in low income countries such as India, Rest of South Asia, and Sub-Saharan Africa is larger than other counters. The share of food and feed is also small everywhere, in particular in rich countries. The share of biofuels is almost zero across the world in 2004, and it slightly increases in 2011.

The share of agriculture has decreased in many regions in 2011. However, the share of food and feed has increased in most regions. The share of biofuels in gross output has increased in several regions, but it dropped in Brazil. Finally, it is important to point out that the share of traditional energy has increased significantly in most regions. This is basically due to the higher energy prices in 2011. In the US, the leading biofuel producer, the shares of agriculture, food and feed, biofuels and energy have increased between 2004 and 2011.

2.2. Commodity and sectoral values

Intermediate and final demands

In general domestic demand for goods and services (domestic or imported) in each region can be divided into two broad categories of intermediate and final demands. The first group represents commodities used in the production processes by firms. For example, firms use electricity to produce goods and services. The second group represents household and government demands for good and services. Since significant changes in the composition of demands may be important for GTAP simulation results, here we examine important changes in the composition of demands for various good and services.

Table 12 represents the distribution of demand between these two broad categories in each region. This table indicates that the share of intermediate demand across regions varies from 50% to 70% in 2004 and 2011. The only exception is China with more than 80% share for intermediate demand.

Table 12 also shows that the share of intermediate demand has increased in 2011 compared with 2004 in many regions (including US) and also at the global level. This means that in general the intermediate demand has a bigger share in domestic demand for goods and services in 2011.

Table 12. Distribution of final demand between intermediate and final uses by region in 2004 and 2011

Region	2004		2011		Difference 2011-2004	
	Intermediate demand (%)	Final demand (%)	Intermediate demand (%)	Final demand (%)	Intermediate demand	Final demand
USA	53.6	46.4	55.5	44.5	1.9	-1.9
European Union	62.2	37.8	62.7	37.3	0.5	-0.5
BRAZIL	60.5	39.5	56.7	43.3	-3.8	3.8
Canada	59.8	40.2	60.4	39.6	0.6	-0.6
JAPAN	61.6	38.4	61.3	38.7	-0.4	0.4
China	80.1	19.9	82.9	17.1	2.8	-2.8
India	60.5	39.5	65.7	34.3	5.1	-5.1
Central America	57.7	42.3	57.1	42.9	-0.6	0.6
South America	60.2	39.8	59.4	40.6	-0.8	0.8
East Asia	71.4	28.6	74.0	26.0	2.6	-2.6
Malaysia and Indonesia	68.1	31.9	70.9	29.1	2.8	-2.8
South East Asia	71.8	28.2	70.6	29.4	-1.2	1.2
South Asia	57.3	42.7	60.2	39.8	2.9	-2.9
Russia	64.1	35.9	64.3	35.7	0.2	-0.2
Central Europe	60.2	39.8	64.2	35.8	4.0	-4.0
Other European countries	60.3	39.7	63.2	36.8	2.8	-2.8
Middle E. and N. Africa	58.3	41.7	62.0	38.0	3.6	-3.6
Sub Saharan Africa	59.5	40.5	57.8	42.2	-1.7	1.7
Oceania	60.6	39.4	64.4	35.6	3.8	-3.8
World	61.0	39.0	64.2	35.8	3.3	-3.3

Here we examine distribution of demand between intermediate and final uses for the US economy with more detail by commodity as shown in Table 13. This table represents the intermediate and final demands for 8 different categories including: crops, livestock, forest, food and feed, biofuels, traditional energy, blended fuel, and others.

As shown in table 13 the share of intermediate demand for crops has significantly increased in the US in 2011. That is basically due to the expansion in using corn and oilseeds as feedstocks for biofuel production. This is a major change in composition of demand for crops. The share of intermediate demand for livestock also has increased in 2011. That is due to an increase in the

share of exports in final demand for livestock. We will discuss this in the next section. As shown in table 13, no major change has happened in the composition of demand for forest products. However, the share of intermediate demand for food and feed has increased in 2011. This is due to producing more DDGS and oilseed meals in 2011.

Table 13 shows 70% and 30% shares for intermediate and final uses of biofuels in 2004. These figures are 100% and 0% in 2011. These changes are due to a change in the way we handle biofuel blending and demand in building the GTAP-BIO data base for 2011. We will explain these changes in detail in section 3.

Table 13. Distribution of final demand between intermediate and final uses in US in 2004 and 2011

Region	2004		2011		Difference 2011-2004	
	Intermediate demand (%)	Final demand (%)	Intermediate demand (%)	Final demand (%)	Intermediate demand	Final demand
Crops	59.9	40.1	71.6	28.4	11.8	-11.8
Livestock	85.1	14.9	91.7	8.3	6.7	-6.7
Forest	76.6	23.4	76.3	23.7	-0.3	0.3
Food and feed	40.7	59.3	44.8	55.2	4.1	-4.1
Biofuels	69.7	30.3	100.0	0.0	30.3	-30.3
Traditional energy	78.1	21.9	83.4	16.6	5.3	-5.3
Blend fuel	-	-	54.9	45.1	-	-
Others	52.6	47.4	53.0	47.0	0.4	-0.4
Total	53.6	46.4	55.5	44.5	1.9	-1.9

Domestic and export uses

In general, commodities produced in each region can be either used domestically (by firms as intermediate inputs and/or final demands) or exported to other regions. Table 14 compares distributions of total output of each region among domestic and export uses in 2004 and 2011.

Table 14. Distribution of production between domestic and exported uses by region in 2004 and 2011

Region	2004		2011		Difference 2011-2004	
	Domestic uses (%)	Exported (%)	Domestic uses (%)	Exported (%)	Domestic uses	Exported
USA	94.7	5.3	93.5	6.5	-1.3	1.3
European Union	83.0	17.0	80.3	19.7	-2.7	2.7
BRAZIL	89.5	10.5	93.7	6.3	4.2	-4.2
Canada	81.5	18.5	85.1	14.9	3.5	-3.5
JAPAN	92.5	7.5	92.0	8.0	-0.6	0.6
China	84.0	16.0	90.1	9.9	6.1	-6.1
India	91.3	8.7	90.6	9.4	-0.6	0.6
Central America	83.0	17.0	82.5	17.5	-0.5	0.5
South America	83.6	16.4	86.8	13.2	3.2	-3.2
East Asia	76.4	23.6	76.2	23.8	-0.2	0.2
Malaysia and Indonesia	69.7	30.3	82.2	17.8	12.5	-12.5
South East Asia	61.0	39.0	68.8	31.2	7.8	-7.8
South Asia	89.3	10.7	91.7	8.3	2.4	-2.4
Russia	84.1	15.9	87.7	12.3	3.6	-3.6
Central Europe	80.6	19.4	84.3	15.7	3.7	-3.7
Other European countries	75.4	24.6	74.8	25.2	-0.6	0.6
Middle E. and N. Africa	73.5	26.5	74.1	25.9	0.6	-0.6
Sub Saharan Africa	80.7	19.3	82.8	17.2	2.1	-2.1
Oceania	89.7	10.3	88.7	11.3	-0.9	0.9
World	86.6	13.4	86.2	13.8	-0.4	0.4

Table 14 shows that most regions consume about 70% to 90% of their domestic products. The US and Japan consume more than 90% of their domestic products while Malaysia-Indonesia and Rest of South East Asia consume less than 70%. At the global scale the share of consumption has not significantly changed. However, major changes have occurred in Brazil, China, Malaysia-Indonesia, and Rest of South Asia between 2004 and 2011 as shown in Table 14. In these regions the share of domestic consumption has increased, significantly.

While, in general, the US economy exports only about 5% to 6% of its domestic products, it exports a large portion of its agricultural products to the rest of the world. Given the large share of

US in the global trade of agricultural products, we examine the shares of domestic and export uses by commodity for the US as shown in Table 15.

Table 15. Distribution of US production between domestic and exported uses in 2004 and 2011

Region	2004		2011		Difference 2011-2004	
	Domestic uses (%)	Exported (%)	Domestic uses (%)	Exported (%)	Domestic uses	Exported
Paddy Rice	66.3	33.7	65.0	35.0	-1.3	1.3
Wheat	25.4	74.6	33.3	66.7	8.0	-8.0
Sorghum	72.7	27.3	80.8	19.2	8.2	-8.2
Coarse grains	68.1	31.9	78.7	21.3	10.6	-10.6
Oilseeds	55.7	44.3	54.3	45.7	-1.4	1.4
Sugar crops	100.0	0.0	100.0	0.0	0.0	0.0
Other crops	83.4	16.6	73.9	26.1	-9.5	9.5
Livestock	97.2	2.8	96.5	3.5	-0.7	0.7
Forest	91.1	8.9	89.8	10.2	-1.3	1.3
Food and feed	95.1	4.9	91.8	8.2	-3.3	3.3
Biofuels	100.0	0.0	94.8	5.2	-5.2	5.2
Traditional energy	97.2	2.8	90.5	9.5	-6.7	6.7
Fuel Blend	-	-	100.0	0.0	-	-
Others	94.8	5.2	93.8	6.2	-0.9	0.9
Total	94.7	5.3	93.5	6.5	-1.3	1.3

Table 15 shows that 35%, 66%, 17%, 19%, 53%, and 26% of the value of paddy rice, wheat, Sorghum, coarse grains, oilseeds, and other US crops were exported in 2011. These shares were lower than their corresponding figures in 2004 for wheat, sorghum, and other coarse grains and higher for the rest of the crop categories listed above. The reductions in the export shares for wheat, sorghum, and other coarse grains (basically corn) have occurred in part because of the rapid expansion in ethanol production in US during the time period of 2004 and 2011. Converting corn to ethanol has affected exports of corn directly. Reduction in exports of wheat and sorghum could be due to indirect impacts of ethanol production. With higher demand for corn the US land shifted to corn from other crops between 2004 and 2011. Harvested areas of wheat and sorghum decreased by 1.7 and 1 million hectares in the US during this time period.

Table 15 also shows that the export share for biofuels has also increased from 0% in 2004 to 5% in 2011. This is due to exporting a portion of ethanol produced in US to other countries in

2011. The US export share for traditional energy also has increased form 3% in 2004 to 10% in 2011. This could be due to higher exports of coal in 2011.

Cost structure

The regional GTAP input-output tables represent the cost structure of firms/industries in each region. Each firm uses primary inputs (a mix of labor, land, capital, and resources) and intermediate inputs (a mix of different goods and service) in its production process. Here we first examine cost at the regional level. To accomplish this task we collapse all primary inputs in one category (primary input) and all intermediate inputs into two categories of non-energy and energy inputs. We also sum the costs over industries to provide an overview of the cost structure of each region. Table 16 shows the shares of primary inputs, non-energy intermediate inputs and energy inputs in total production costs of each region in 2004 and 2011.

Table 16. Distribution of production costs among primary non-energy and energy inputs by region in 2004 and 2011

Region	2004			2011			Difference 2011-2004		
	Primary inputs (%)	Non-energy intermediate inputs (%)	Energy inputs (%)	Primary inputs (%)	Non-energy intermediate inputs (%)	Energy inputs (%)	Primary inputs	Non-energy intermediate inputs	Energy inputs
USA	48.8	47.4	3.8	46.7	46.7	6.6	-2.0	-0.8	2.8
European Union	40.5	56.0	3.6	40.0	52.0	8.0	-0.4	-4.0	4.4
BRAZIL	44.9	47.6	7.4	47.6	46.9	5.5	2.7	-0.8	-1.9
Canada	44.5	50.6	4.9	44.4	49.1	6.5	-0.1	-1.5	1.6
JAPAN	44.4	52.4	3.2	42.4	51.2	6.4	-1.9	-1.2	3.2
China	27.9	66.0	6.0	28.3	65.5	6.2	0.4	-0.6	0.2
India	42.7	46.7	10.5	39.4	47.9	12.7	-3.3	1.2	2.2
Central America	37.1	56.4	6.5	47.2	45.4	7.4	10.1	-10.9	0.9
South America	45.7	47.4	6.9	46.0	46.7	7.2	0.3	-0.7	0.4
East Asia	35.6	57.0	7.4	33.1	56.4	10.4	-2.4	-0.6	3.1
Malaysia and Indonesia	41.1	51.9	7.0	38.1	54.0	7.8	-3.0	2.1	0.9
South East Asia	33.9	58.1	8.0	35.9	52.7	11.4	2.0	-5.4	3.4
South Asia	43.7	49.7	6.6	40.1	51.7	8.2	-3.6	2.0	1.6
Russia	41.2	43.8	15.0	41.6	42.5	15.9	0.4	-1.3	0.9
Central Europe	41.7	45.7	12.6	38.4	48.4	13.3	-3.3	2.7	0.6
Other European countries	47.7	49.9	2.4	45.1	50.8	4.1	-2.6	0.9	1.7
Middle E. and N. Africa	47.3	41.5	11.2	48.4	39.0	12.6	1.1	-2.5	1.4
Sub Saharan Africa	44.3	51.1	4.5	46.3	47.6	6.1	2.0	-3.5	1.6
Oceania	44.0	52.5	3.5	41.7	53.2	5.1	-2.3	0.6	1.6
World	42.7	52.6	4.7	40.6	51.6	7.8	-2.1	-1.0	3.1

As shown in Table 16, in general the share of primary inputs varies around 40% with some exceptions. For example, the share of primary inputs was about 28% (the world's lowest share for primary inputs) in China in both years, while the corresponding share for the US economy was 49% (the world's highest share for primary inputs) in 2004 and 47% in 2011. The share of non-energy intermediate inputs varies around 50% again with some exceptions. Finally, as shown in Table 16, the share of energy varies between 5% and 15%. It is important to note that the share of energy in total production costs has increased everywhere (except for Brazil) between 2004 and 2011.

We now analyze the firms' cost structures for the US economy as presented in Table 17. In this table we aggregated the US industries into 9 broad groups. The inputs are divided into the three categories as defined above. This table indicates that the cost shares vary significantly across industries, and some of them changed between 2004 and 2011. For example, while the share of primary inputs in crop industries is relatively large (56% in 2004 and 52% in 2011), this share in livestock is considerably lower (26% in 2004 and 21 in 2011).

Table 17. Cost structure of US economy by major industry groups in 2004 and 2011

Industry groups	2004			2011			Difference 2011-2004		
	Primary inputs (%)	Non-energy intermediate inputs (%)	Energy inputs (%)	Primary inputs (%)	Non-energy intermediate inputs (%)	Energy inputs (%)	Primary inputs	Non-energy intermediate inputs	Energy inputs
Crop	56.0	40.5	3.6	51.9	42.9	5.2	-4.1	2.4	1.7
Livestock	25.8	72.5	1.7	20.6	76.3	3.1	-5.1	3.7	1.4
Forestry	50.1	49.0	0.9	50.2	48.5	1.3	0.1	-0.4	0.3
Food and feed	32.7	65.6	1.7	29.4	69.1	1.5	-3.3	3.5	-0.1
Grain ethanol	52.2	38.3	9.5	14.0	80.5	5.5	-38.2	42.3	-4.0
Biodiesel	27.6	70.1	2.3	7.7	90.5	1.8	-19.9	20.4	-0.5
Blender	-	-	-	0.0	0.0	100.0	-	-	-
Traditional energy	34.1	19.9	46.0	29.2	17.2	53.6	-4.9	-2.8	7.6
Others	49.9	47.9	2.2	49.2	48.2	2.6	-0.7	0.3	0.4
Total	48.8	47.4	3.8	46.7	46.7	6.6	-2.0	-0.8	2.8

Table 17 shows that the cost shares for grain ethanol have significantly changed between 2004 and 2011. The share of primary inputs in ethanol production has dropped from 52% in 2004 to 18.5% in 2011. On the other hand the share of non-energy intermediate inputs in ethanol production has increased from 38% in 2004 to 76.1% in 2011. In 2004 the ethanol industry was a new industry and capital was a major cost item for the industry. On the other hand the price of corn (the feedstock for ethanol industry in US) was lower. Therefore, the share of capital was large and the share of corn (the main component of non-energy intermediate inputs) was smaller in 2004.

In 2011 the ethanol industry is an established industry. Unlike 2004, in 2011 capital cost was not a major cost component for ethanol production for existing plants. Any new plants would have a higher capital cost share, but an input-output table captures the average values for the existing industry. On the other hand, the cost of corn was the largest cost component for the industry in 2011. The average price of corn used by ethanol producer was about $6.22 per bushel in 2011 (2.6 times the 2004 price in nominal terms).

2.3. Biophysical data

The GTAP-BIO database includes data on land cover, harvested area, and crop production by region. It also represents cropland pasture in a few counties. Here we examine changes in these variables between 2004 and 2011.

Land cover

First consider table 18 which provides forest, cropland, and pasture areas in 2004 and 2011. This table shows that the area of accessible managed land (sum of forest, cropland, and pasture) has decreased by about 16.4 million hectares at the global scale between 2004 and 2011. During this time period the largest reductions in accessible land occurred in Oceania (by 21.2 million hectares), Middle East & North Africa (by 21.9 million hectares), and US (by 6.4 million hectares) and the largest expansions were in Sub-Saharan Africa (by 14.7 million hectares), China (by 11.9 million hectares), and South America (by 5.8 million hectares).

At the global scale areas of forest and cropland have increased by 7.8 and 17.5 million hectares, respectively, while area of pasture land has decreased by 41.7 million hectares. This means that at the global scale, the livestock industry in 2011 is using less land directly compared with 2004. At the regional level, the largest expansion in cropland occurred in Sub-Saharan Africa (by 15.7

million hectares), and the largest reduction was observed in the US (by 10.5 million hectares). The reduction in areas of cropland in US has happened while demand for corn and soybeans were increasing due partly to expansion in biofuel production. That induced major changes in allocation of cropland among crops in favor of corn and also soybeans.

Table 18. Forest, cropland and pasture areas by region in 2004 and 2011

(Figures are million hectare)

Region	2004				2011				Difference 2011-2004			
	Forest	Cropland	Pasture	Total	Forest	Cropland	Pasture	Total	Forest	Cropland	Pasture	Total
USA	229	176	229	633	232	165	229	627	3.7	-10.5	0.4	-6.4
European Union	153	125	60	338	155	123	60	338	2.3	-2.3	0.0	0.1
BRAZIL	156	61	176	392	154	63	174	390	-2.5	2.0	-1.9	-2.4
Canada	100	40	20	160	101	36	20	156	0.1	-3.7	-0.5	-4.0
JAPAN	18	4	0	22	18	4	0	22	0.0	-0.1	0.0	-0.1
China	144	141	277	562	152	144	277	573	8.4	3.5	0.0	11.9
India	18	171	11	200	18	172	10	200	0.2	0.2	-0.4	0.0
Central America	49	57	84	190	49	57	84	190	0.0	0.5	-0.5	0.1
South America	109	59	254	422	107	64	256	428	-1.7	5.5	2.0	5.8
East Asia	17	5	76	99	17	5	77	99	-0.3	-0.3	0.4	-0.3
Malaysia and Indonesia	40	72	2	114	40	75	2	117	-0.4	3.1	0.0	2.7
South East Asia	96	53	5	154	94	59	5	157	-2.3	5.4	0.2	3.3
South Asia	8	47	37	92	8	48	37	92	-0.2	0.7	0.0	0.5
Russia	267	125	79	470	267	124	79	470	0.2	-0.7	-0.1	-0.5
Central Europe	51	112	280	443	54	110	280	444	2.3	-1.4	-0.6	0.3
Other European countries	28	1	1	30	30	1	1	32	1.1	0.0	0.0	1.1
Middle E. and N. Africa	1	54	152	207	2	54	129	185	0.3	0.2	-22.4	-21.9
Sub Saharan Africa	187	211	729	1127	184	227	732	1142	-3.5	15.7	2.5	14.7
Oceania	5	34	272	311	5	34	251	290	0.0	-0.3	-20.8	-21.2
World	1678	1544	2746	5968	1686	1562	2704	5952	7.8	17.5	-41.7	-16.4

Harvested area

Table 19 represents harvested area by region and by crop type in 2004 and 2011. At the global scale harvested area has increased by 94 million hectares between 2004 and 2011. As mentioned earlier in this paper the area of cropland has increased by 17.5 million hectares during the same time period. Comparing these two figures indicates that the harvested area has grown faster than land cover between 2004 and 2011. This could be due to some combination of reductions in crop failure and idled land and increases in double cropping across the world between 2004 and 2011.

The largest expansions in harvested area occurred in Sub-Saharan Africa (by 32.5 million hectares), India (by 21.9 million hectares), and China (by 13.7 million hectares). Harvested area has decreased in a few regions slightly. The largest apparent reduction in harvested area was in Canada. However, this is not an actual reduction but due to a correction in harvested area for this region in the GTAP data base for 2011 versus 2004. In US harvested area decreased by 2.1 million hectares while cropland area dropped by 10.5 million hectares. This could be due to reductions in crop failure and idled land and/or increases in double cropping.

Among crops at the global scale, the largest expansion in harvested area is for oilseeds (by 33.2 million hectares). Production of oilseeds has increased in many regions across the world. At the global scale, the smallest increase in harvested area was for wheat. The harvested area of wheat has increased only by 3.4 million hectares between 2004 and 2011.

Harvested area has decreased in all crop categories in US, except for coarse grains. The harvested area of coarse grains has increased by 2 million hectares. This reflects the need for more corn for ethanol production in the US. In the EU the harvested area of almost all crops has decreased, except for oilseeds. This reflects the need for more oilseeds for biodiesel production in the EU.

Table 19. Harvested area by crop and by region in 2004 and 20011

(Figures are million hectare)

Region	2004						2011					
	Cr1	Cr2	Cr3	Cr4	Cr5	Total	Cr1	Cr2	Cr3	Cr4	Cr5	Total
USA	1.3	20.2	35.2	31.8	39.4	128.0	1.1	18.5	37.2	31.5	37.7	125.9
European Union	0.4	26.6	33.8	13.9	41.0	115.7	0.5	26.1	30.0	16.7	39.6	112.9
BRAZIL	3.7	2.8	13.9	22.3	20.1	62.8	2.8	2.1	14.3	24.8	24.1	68.1
Canada	0.0	9.4	6.8	6.9	10.4	33.5	0.0	8.5	4.9	9.4	5.6	28.5
JAPAN	1.7	0.2	0.1	0.1	2.0	4.2	1.6	0.2	0.1	0.1	1.7	3.7
China	28.6	21.6	29.4	24.2	57.0	160.8	30.1	24.3	36.7	22.0	61.5	174.6
India	41.9	26.6	29.3	27.5	61.5	186.8	44.0	29.1	27.5	28.9	79.3	208.7
Central America	0.7	0.5	12.3	1.1	12.0	26.7	0.8	0.7	11.0	1.0	11.9	25.4
South America	2.1	7.4	7.6	20.3	19.2	56.6	2.4	6.3	10.6	26.9	16.9	63.0
East Asia	1.6	0.2	0.7	0.4	1.9	4.9	1.4	0.4	0.7	0.4	1.8	4.7
Malaysia and Indonesia	12.6	0.0	3.4	11.0	9.0	36.0	13.9	0.0	3.9	14.8	13.5	46.0
South East Asia	31.0	0.1	5.5	7.9	15.7	60.2	35.5	0.1	6.2	8.8	20.5	71.1
South Asia	15.3	11.4	3.6	2.2	11.2	43.7	17.4	12.3	3.7	2.1	12.0	47.5
Russia	0.1	22.9	17.4	5.7	35.1	81.2	0.2	24.8	15.6	9.7	31.1	81.4
Central Europe	0.3	32.2	21.2	7.1	34.1	95.0	0.3	33.7	19.6	11.5	31.9	97.0
Other European countries	0.0	0.2	0.3	0.0	0.6	1.2	0.0	0.2	0.3	0.0	0.7	1.1
Middle E. and N. Africa	1.3	18.1	10.7	4.2	15.7	49.9	1.2	16.7	10.4	4.8	15.8	49.0
Sub Saharan Africa	7.7	2.9	72.3	21.6	71.4	175.8	10.2	2.8	85.1	27.3	83.0	208.3
Oceania	0.1	13.4	6.9	1.8	20.0	42.2	0.1	13.6	5.6	2.6	20.3	42.1
World	150.5	216.8	310.4	210.2	477.3	1365.2	163.3	220.3	323.3	243.4	508.7	1458.9

Cr1, Cr2, Cr3, Cr4, and Cr5 represent Paddy rice, Wheat, Coarse Grains, Oilseeds, and Other crops, respectively.

Crop production

Table 20 represents crop production by region and by crop type in 2004 and 2011. It shows that at the global level production of paddy rice, wheat, coarse grains, oilseeds, and other crops increased by 115.4 million metric tons (MMT), 66.8 MMT, 127.7 MMT, 178 MMT, and 907.3 MMT, repressively, between 2004 and 2011. The per capita production for all of these crop categories has also increased by 9 kg, 1.8 kg, 5.5 kg, 18.7 kg, and 52 kg, respectively. Thus, more food is available to consume per person. Of course, some of these crops are consumed for non-food uses (e.g. corn for ethanol or oilseeds for biodiesel), but some of them (like rice and wheat) are basic food crops.

As shown in Table 20 the largest increases in crop production have occurred in Brazil (by 368.6 MMT), China (by 325.7 MMT), India (by 305.9 MMT), and Sub-Saharan Africa (by 128.2 MMT) between 2004 and 2011. Table 20 also shows that crop production has fallen (by 68.4 MMT) in Canada. Again, that is basically due to a correction in the GTAP data for Canada as indicated above. In other words, it is not a real decrease, just a data correction. In the US only production of coarse grains has increased by 4.2 MMT, while production of other crops has decreased between 2004 and 2011.

Table 20: Crop production by crop and by region in 2004 and 20011

(Figures are in million metric ton)

Region	2004						2011					
	Cr1	Cr2	Cr3	Cr4	Cr5	Total	Cr1	Cr2	Cr3	Cr4	Cr5	Total
USA	10.5	58.7	319.8	89.0	843.1	1321.1	8.4	54.4	324.0	87.7	815.3	1289.8
European Union	2.9	149.3	172.9	36.1	982.0	1343.3	3.1	137.9	149.7	42.4	1010.7	1343.9
BRAZIL	13.3	5.8	44.9	53.7	501.1	618.8	13.5	5.7	58.4	79.6	830.2	987.4
Canada	0.0	24.8	26.0	11.6	115.5	177.9	0.0	25.3	22.0	18.9	43.3	109.5
JAPAN	10.9	0.9	0.2	0.2	64.6	76.7	10.5	0.7	0.2	0.2	50.0	61.7
China	180.5	92.0	140.7	49.4	859.2	1321.8	201.0	117.4	200.4	48.9	1079.8	1647.5
India	124.7	72.2	33.0	31.4	503.2	764.4	157.9	86.9	43.1	41.7	740.8	1070.3
Central America	2.2	2.3	33.5	5.3	207.3	250.7	2.9	3.6	29.5	7.2	224.2	267.5
South America	11.1	19.7	30.1	47.6	349.6	458.1	12.8	20.0	47.9	74.1	319.1	473.9
East Asia	9.1	0.3	2.3	0.5	24.7	36.9	8.8	0.6	2.3	0.5	22.8	35.0
Malaysia and Indonesia	56.4	0.0	11.3	149.5	77.7	294.8	68.3	0.0	17.7	216.0	88.1	390.2
South East Asia	110.6	0.1	14.8	26.6	218.4	370.5	134.5	0.2	20.7	33.8	280.3	469.5
South Asia	51.4	24.5	6.3	3.6	105.8	191.6	68.9	31.3	9.1	3.8	118.9	232.1
Russia	0.5	45.4	30.3	5.7	295.1	377.0	1.1	56.2	34.5	13.1	291.0	395.9
Central Europe	1.2	66.6	59.2	8.6	307.5	443.3	1.8	84.7	71.0	19.5	330.0	507.0
Other European countries	0.0	0.9	1.6	0.1	18.5	21.1	0.0	0.8	1.2	0.1	20.0	22.1
Middle E. and N. Africa	9.2	41.4	20.0	4.8	237.5	312.9	8.7	39.4	21.6	5.9	279.2	354.8
Sub Saharan Africa	12.6	5.3	79.6	31.9	381.4	510.8	20.3	6.3	101.0	38.5	472.9	639.0
Oceania	0.6	22.2	12.6	3.6	257.3	296.4	0.7	27.8	12.5	5.5	239.9	286.4
World	607.7	632.5	1039.1	559.5	6349.3	9188.2	723.2	699.4	1166.8	737.5	7256.6	10583.5

Cr1, Cr2, Cr3, Cr4, and Cr5 represent Paddy rice, Wheat, Coarse Grains, Oilseeds, and Other crops, respectively.

Yield

Table 21 represents crop yields by region and by crop type in 2004 and 2011. It indicates that crop yields have increased in many regions across the world. At the global scale rice, wheat, coarse grains, oilseeds, and other crop yields have increased by 9.7%, 8.8%, 7.8%, 13.8%, and 7.2% respectively, between 2004 and 2011.

The largest growth in crop yields occurred in Brazil (ranging from 26% to 38%), India (ranging from 10% to 40%), Russia (ranging from 10% to 35%), and members of the former Soviet Union (ranging from 15% to 40%). In many other regions yields also increased by large percentages as shown in Table 21. This table shows minor reductions in some crop yields in a few regions as well. The only large reduction in yield belongs to other crops in Canada which is again due to a correction in data for this country, and does not represent a real reduction.

In the US, yield has slightly increased for paddy rice, wheat, and other crops and decreased for coarse grains (by 4%) and soybeans (by 0.2%) between 2004 and 2011. It is important to note that the US corn yield was more than 10 metric tons per hectare in 2004, higher than the normal trend. On the other hand, it was about 9.2 metric tons per hectare in 2011, below the normal trend[5]. Therefore, while corn yield follows an upward trend in the US, our data shows a reduction in coarse grain yield between 2004 and 2011.

[5] The US corn yields for 2004 and 2011 are obtained from the USDA data base.

Table 21. Crop yields by region in 2004 and 20011

(Figures are in metric ton per hectare)

Region	2004						2011					
	Cr1	Cr2	Cr3	Cr4	Cr5	Total	Cr1	Cr2	Cr3	Cr4	Cr5	Total
USA	7.8	2.9	9.1	2.8	21.4	10.3	7.9	2.9	8.7	2.8	21.6	10.2
European Union	6.7	5.6	5.1	2.6	24.0	11.6	6.5	5.3	5.0	2.5	25.6	11.9
BRAZIL	3.6	2.1	3.2	2.4	24.9	9.8	4.9	2.7	4.1	3.2	34.4	14.5
Canada	0.0	2.6	3.8	1.7	11.1	5.3	0.0	3.0	4.5	2.0	7.7	3.8
JAPAN	6.4	4.0	2.1	1.3	32.0	18.3	6.7	3.5	1.7	1.7	30.2	16.6
China	6.3	4.3	4.8	2.0	15.1	8.2	6.7	4.8	5.5	2.2	17.6	9.4
India	3.0	2.7	1.1	1.1	8.2	4.1	3.6	3.0	1.6	1.4	9.3	5.1
Central America	3.2	4.4	2.7	4.9	17.2	9.4	3.7	5.4	2.7	6.9	18.9	10.5
South America	5.2	2.7	4.0	2.3	18.2	8.1	5.4	3.2	4.5	2.8	18.9	7.5
East Asia	5.7	1.3	3.3	1.2	13.2	7.6	6.2	1.7	3.1	1.2	12.9	7.4
Malaysia and Indonesia	4.5	0.0	3.3	13.6	8.6	8.2	4.9	0.0	4.6	14.6	6.5	8.5
South East Asia	3.6	1.3	2.7	3.4	13.9	6.2	3.8	1.8	3.3	3.8	13.7	6.6
South Asia	3.4	2.1	1.8	1.7	9.4	4.4	4.0	2.6	2.4	1.8	9.9	4.9
Russia	3.8	2.0	1.7	1.0	8.4	4.6	5.1	2.3	2.2	1.4	9.3	4.9
Central Europe	4.0	2.1	2.8	1.2	9.0	4.7	5.5	2.5	3.6	1.7	10.4	5.2
Other European countries	0.0	5.5	5.0	3.0	28.7	18.2	0.0	5.2	4.1	3.0	30.6	19.6
Middle E. and N. Africa	6.8	2.3	1.9	1.1	15.2	6.3	7.0	2.4	2.1	1.2	17.6	7.2
Sub Saharan Africa	1.6	1.8	1.1	1.5	5.3	2.9	2.0	2.3	1.2	1.4	5.7	3.1
Oceania	8.3	1.7	1.8	2.0	12.9	7.0	9.5	2.1	2.2	2.1	11.8	6.8
USA	4.0	2.9	3.3	2.7	13.3	6.7	4.4	3.2	3.6	3.0	14.3	7.3

Cr1, Cr2, Cr3, Cr4, and Cr5 represent Paddy rice, Wheat, Coarse Grains, Oilseeds, and Other crops, respectively.

Cropland pasture

Cropland pasture represents a portion of cropland which has been cultivated and used for crop production in the past, but currently in pasture. The GTAP-BIO 2004 database includes cropland pasture only for US (25 million hectares) and Brazil (23.6 million hectares). The area of cropland pasture in US has dropped to 5.2 million hectares in 2011, according to the US census. Due to the lack of information, we assumed that the area of cropland pasture in Brazil has dropped to 11.8 million hectares in 2011. Finally, with access to new data, about 5.2 million hectares of cropland pasture was added to the database for Canada.

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